ONE SOURCE • **ONE** PURPOSE • **MANY** SOLUTIONS

Vogt Power Emission Control Solutions

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Presented for
Hot Topic Hour
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Vogt Power History

An Industry Leader with a Tradition of Innovation and Excellence

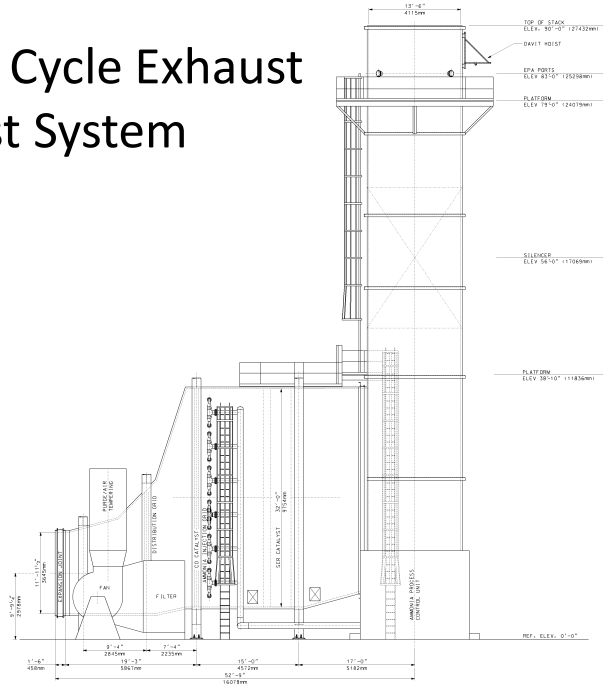
- 1880 Founded by Henry Vogt
- 1962 First HRSG
- 1972 First 3 pressure HRSG
- 1988 First Re-heat HRSG
- 1988 First F-class HRSG
- 2010 Fast Start Capabilities
- 2011 Simple Cycle Exhaust Systems
- 2013 Once Through Steam Generator

Vogt logo
circa 1940

Emission Control Solutions

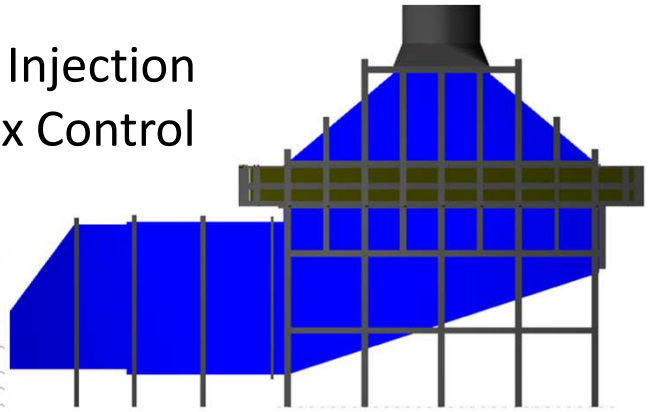
Options for Gas Turbine Emission Control

- Simple Cycle Exhaust Catalyst System



- Combined Cycle HRSG Installation with Catalyst

- Steam Injection for NOx Control



Simple Cycle Emission Control Solutions

Carbon Monoxide (CO) Catalyst System

- The CO Catalyst system uses a precious metal oxidation catalyst to covert CO into CO_2

$$CO + \frac{1}{2}O_2 \rightarrow CO_2$$

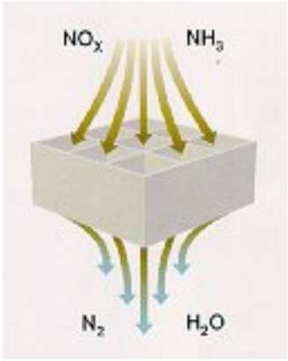
- CO Catalyst Requirements:
  - Uniform velocity distribution within 15% rms
  - Exhaust gas temperature entering at no greater than ±50°F
- CO Catalyst can achieve 2-5 ppmvd@15%O_2, based on 95% reduction
- CO Catalyst tolerate temperatures 425°F to 1150°F
  - Increased oxidation (greater reactivity) at higher temperature
  - Increased contamination rate below 650°F

Simple Cycle Emission Control Solutions

De-NOx Selective Catalytic Reduction (SCR) Catalyst System

- The SCR Catalyst system employs a catalytic reaction to convert ammonia (NH3) and NOx into harmless water (H2O) and nitrogen (N2)

$$4NO + 4NH_3 + O_2 \rightarrow 4N_2 + 6H_2O$$
$$NO + NO_2 + 2NH_3 \rightarrow 2N_2 + 3H_2O$$
$$6NO_2 + 8NH_3 \rightarrow 7N_2 + 12H_2O$$



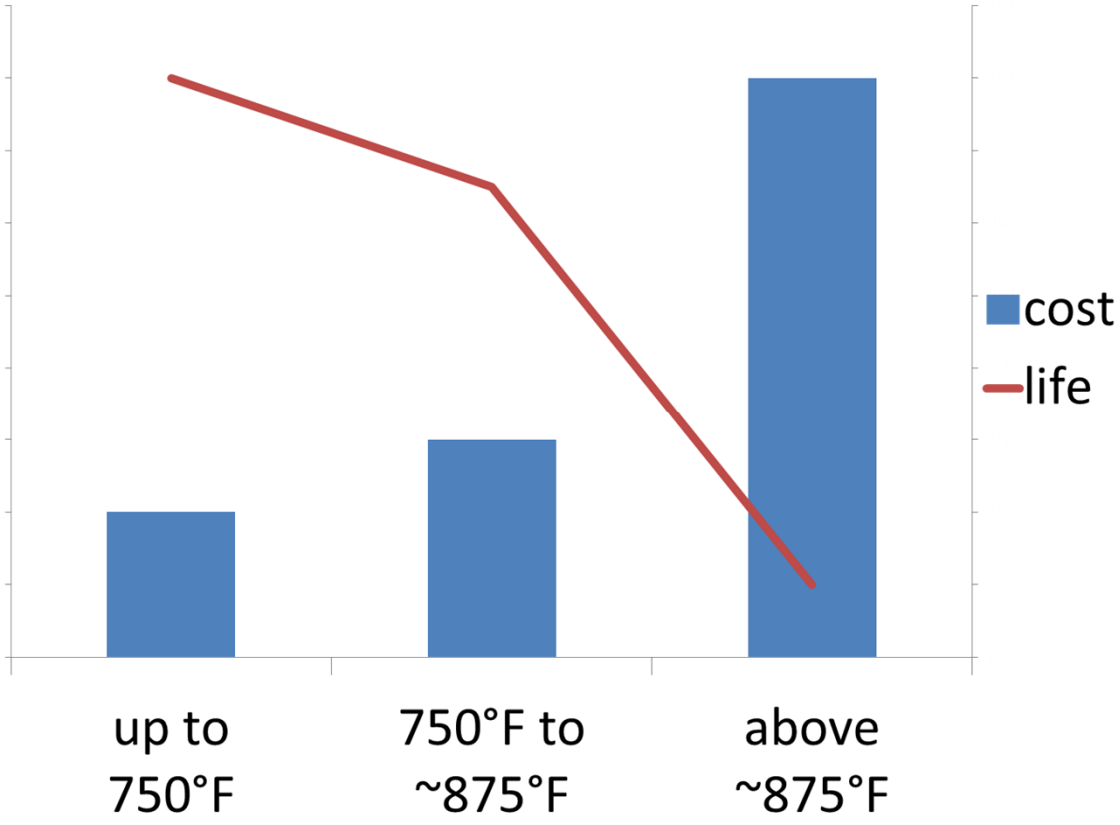
- SCR Catalyst Requirements:
  - Uniform velocity distribution within 15% rms
  - Exhaust gas temperature entering at no greater than ±50°F

- SCR Catalyst can achieve 2-5 ppmvd@15%O_2, based on 95% reduction

Simple Cycle Emission Control Solutions

De-NOx Selective Catalytic Reduction (SCR) Catalyst System

- SCR Catalyst cost and durability are sensitive to operative temperature



Simple Cycle Emission Control Solutions

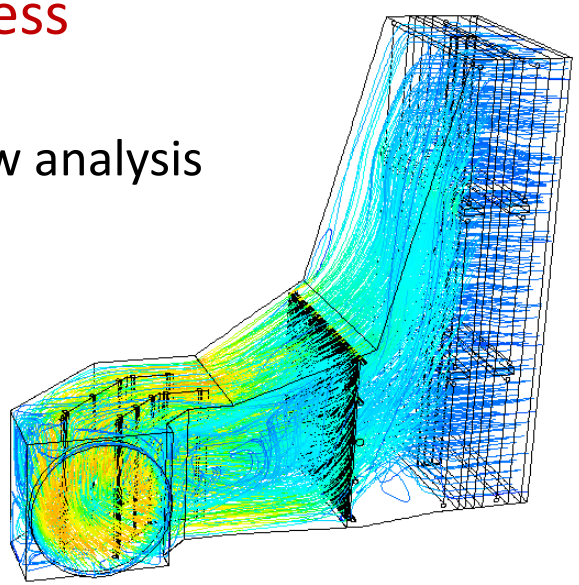
Ammonia Systems for SCR Catalysts

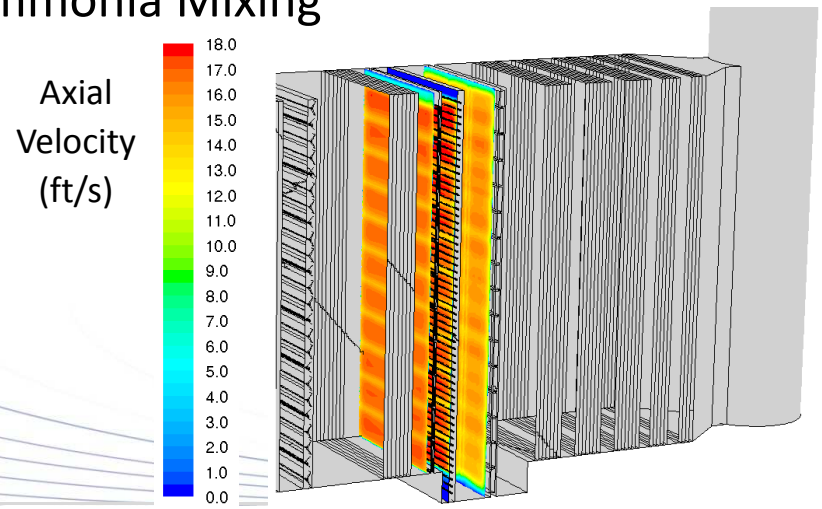
- Ammonia systems for anhydrous or aqueous supply
  - Aqueous ammonia (19% typical) requires larger equipment, greater power consumption, and more constant supply deliveries
  - Anhydrous ammonia requires increased safety measures and risk management
- Ammonia vaporization systems designed for exhaust gas recirculation or ambient air electric heaters
- Ammonia Injection Grid design influences NOx reduction and ammonia slip
- Ammonia slip of 2-10 ppmvd@15%O_2

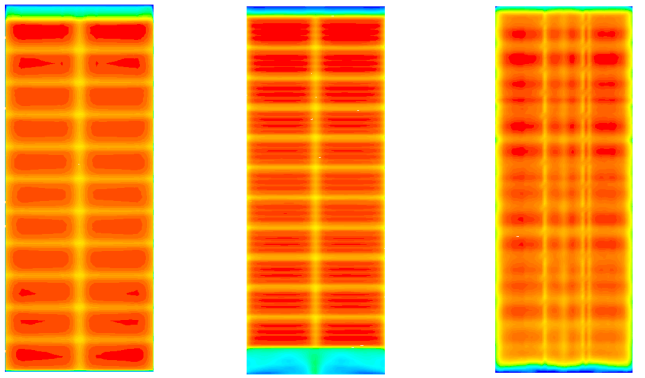
Simple Cycle Emission Control Solutions

Flow Modeling Critical to Project Success

- VPI CFD Engineering uses Fluent software for flow analysis
- Turbine exhaust flow profile
- Duct design and distribution grid requirements
  - Focus on reducing gas side pressure drop
- Dilution Air mixing
- Ammonia Mixing







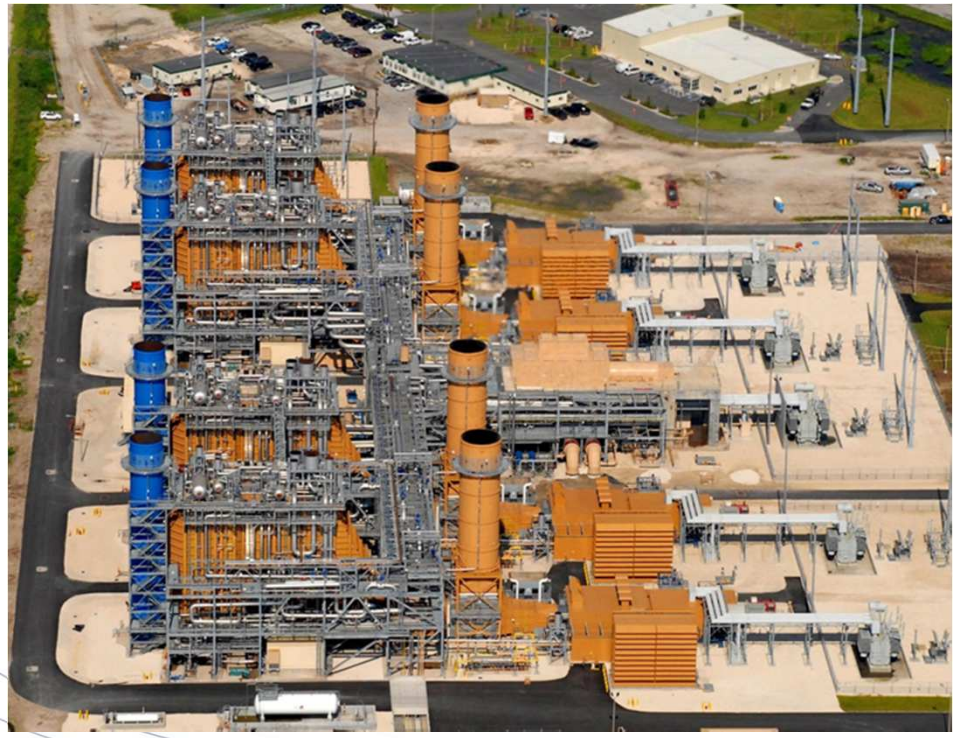
Simple Cycle Emission Control Solutions

Simple Cycle Exhaust Catalyst System

Combined Cycle Emission Control Solutions

New CT and HRSG Installation

- Vogt Power has over 500 HRSG installations operating in 35 countries around the globe, both utility and industrial
- Design for combustion turbines 25 MW to 290 MW
- Proven design for high cycling and CT fast startup



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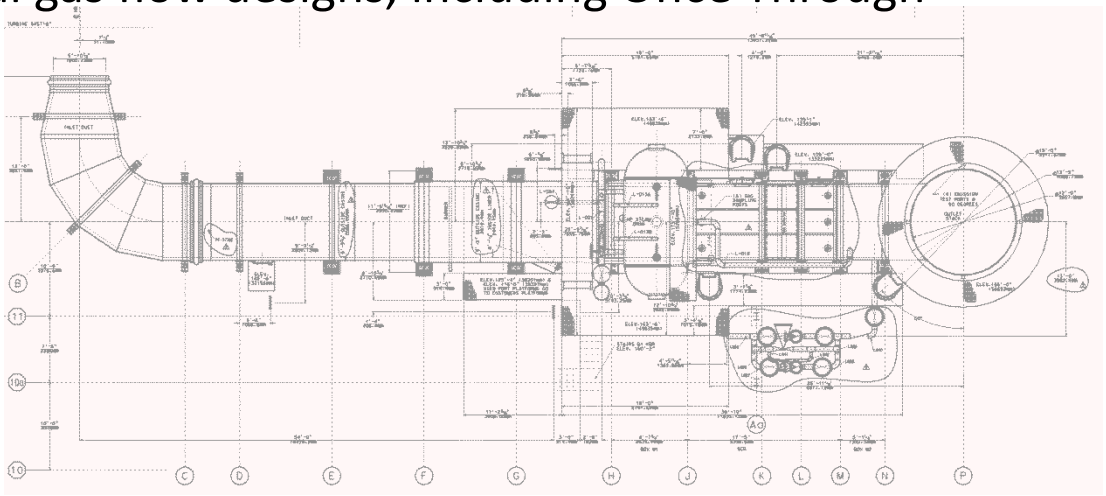
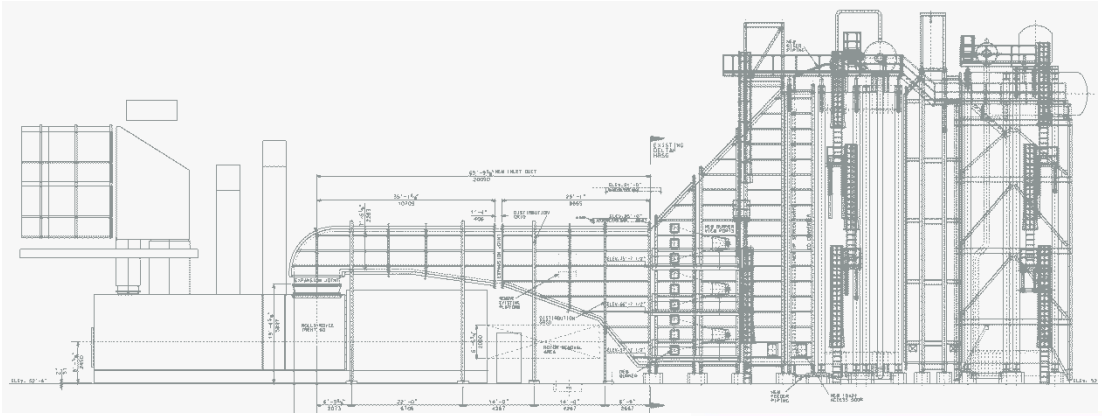
Combined Cycle Emission Control Solutions

Adding Steam Cycle to Simple Cycle CTs

- Design experience for sighting HRSG into existing plants
- Both horizontal and vertical gas flow designs, including Once Through





Combined Cycle Emission Control Solutions

Existing Combined Cycle Installation Without Emission Catalysts

- Vogt Power Aftermarket provides parts and service to all OEM units
- Expertise in HRSG thermal re-rating due to CT upgrade/rerate
- Proven experience installing emission catalyst into existing units

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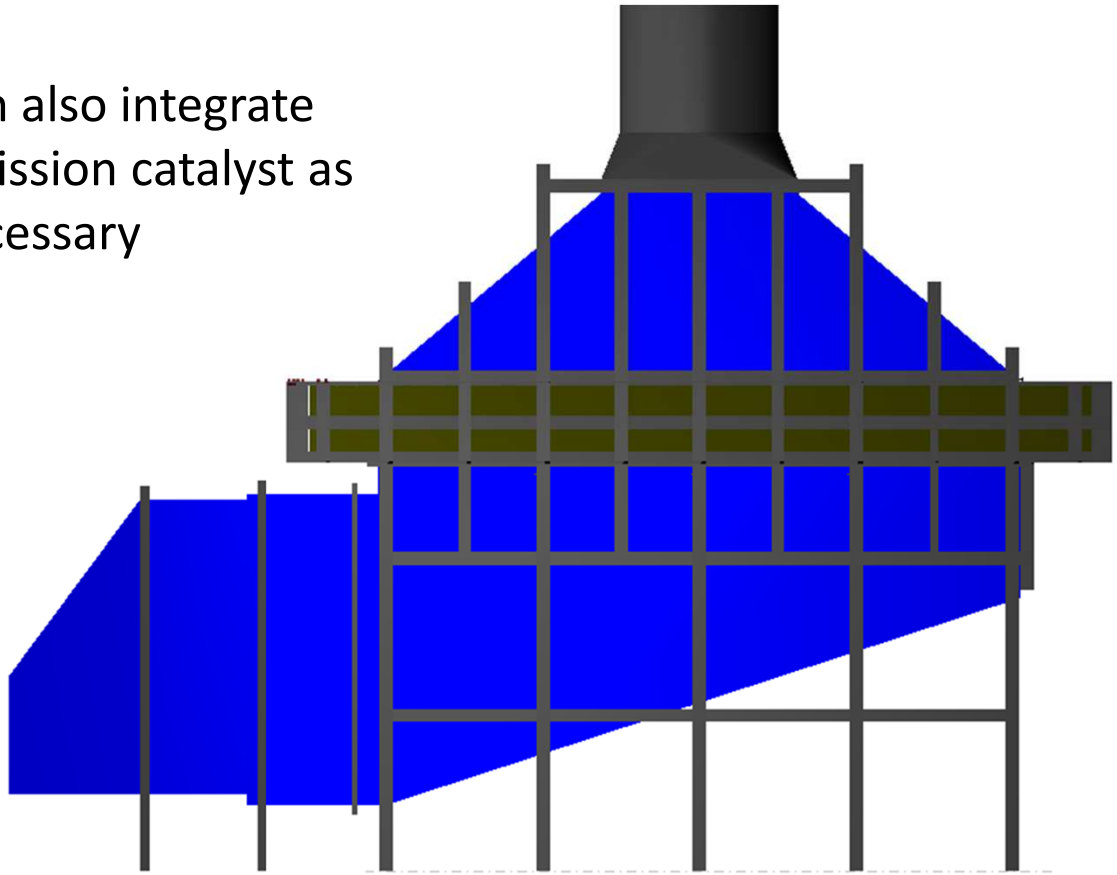
Steam Injection for CT Emission Control Solution

Existing CT Installation

- Can provide heating surface for generating steam to be injection to CT for NOx control and power augmentation
  - Can also integrate emission catalyst as necessary



Emission Control Durability

CO and SCR System Maintenance Concerns

- Poor quality NH3 fouling the control skid, vaporizer, AIG
- Catalyst poisoning due to high sulfur in CT exhaust, impurities in fuel supply or evaporative cooling water, or CT ingestion of dirty air
- Catalyst damage due to over-temperature, water washing, or casing insulation failure